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(71) Applicant
Hughes Aircraft Company

(Incorporated in the USA - Delaware)

7200 Hughes Terrace, Los Angeles, California
90080-0028, United States of America

(72) Inventor
Arnold I Klayman

(74) Agent and/or Address for Service
Carpmaels & Ransford
43 Bloomsbury Square, London, WC1A 2RA,
United Kingdom

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(58) Field of search
UK CL (Edition K) H4J JAB JBA
INT CL[5] H04R 1/20 1/22 1/28

(54) High mass low resonance speaker system

(57) A relatively small size speaker system is caused to have a lower resonant frequency by providing a partitioned enclosure 10 having an air mass in a first of two chambers 20 that is driven to vibrate as a unit by a pair of speakers 24, 30 on different or opposite sides of the chamber. Air within the other one of the chambers is driven by only one of the speakers, and thus operates primarily as a spring, whereas the air in the first chamber is driven by both speakers and acts primarily as a mass. The two speakers are operated in mechanical phase so as to vibrate the air in the first chamber as a unitary mass by imparting mutually aiding forces to the air mass. This adds a significant amount of mass to the vibratory system and consequently lowers resonant frequency.

Further embodiments related to Fig 3 are described (Figs 2, 4) wherein either chamber may be ported.

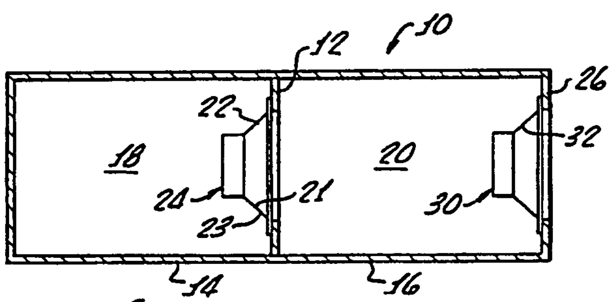

FIG. 1.

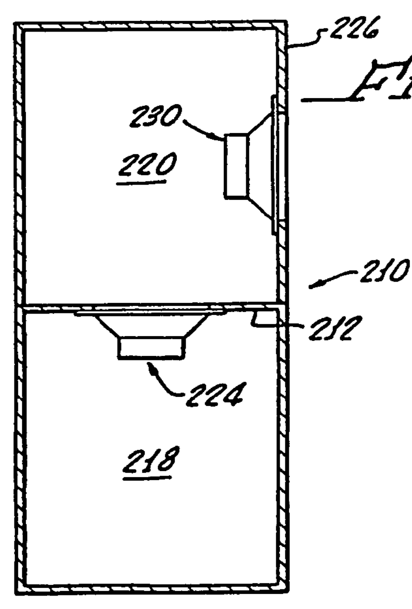

FIG. 3.

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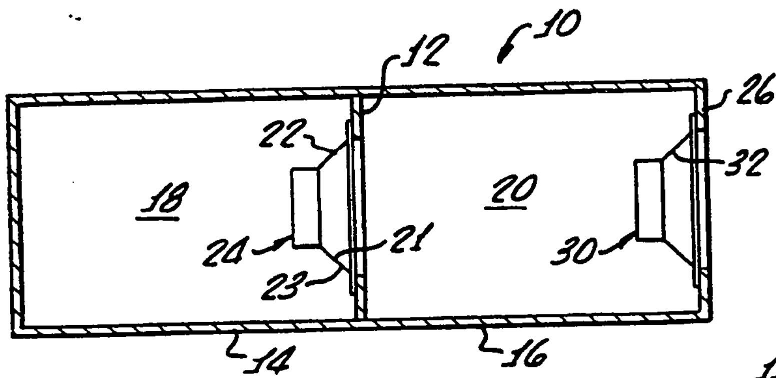

FIG. 1.

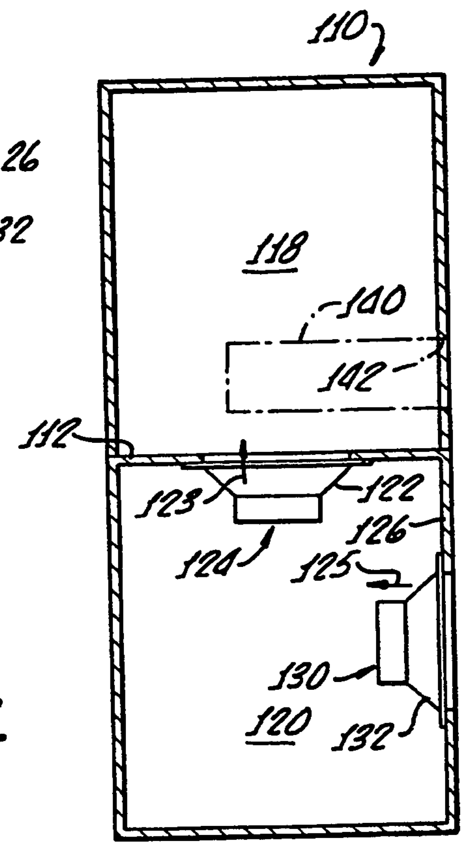

FIG. 2.

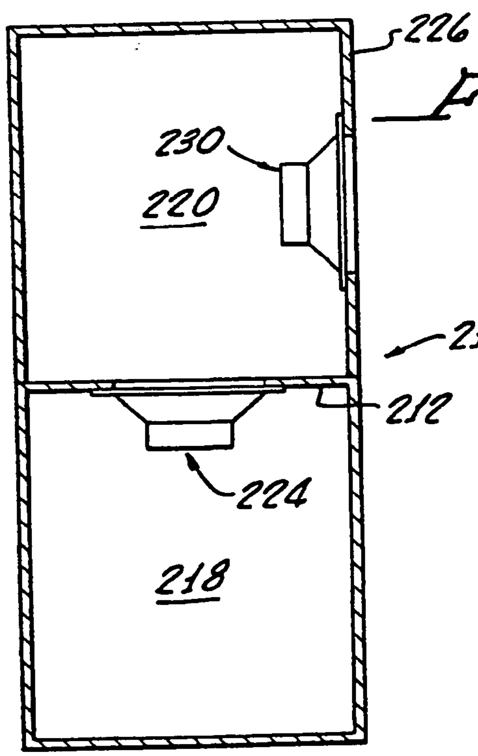

FIG. 3.

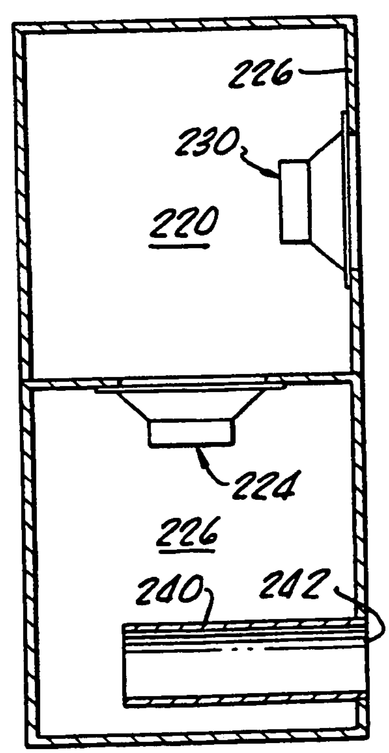

FIG. 4.

HIGH MASS LOW RESONANCE SPEAKER SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to loudspeaker systems and more particularly concerns systems having very low resonant frequencies.

2. Description of Related Art

Loudspeaker systems are often provided with speaker components specifically adapted for operating in different frequency ranges, including low range, mid range and high ranges. Low range components often include special sub-woofer speaker systems operable solely in the lowest frequency ranges, in the order of between about 30 and 100 hertz. Generally such very low sub-woofers systems require large speakers and large enclosures for efficiency of coupling to ambient air and for reproduction of sound in the desired 30 to 100 hertz range. The large size is needed, at least in part, because of the need to control resonant frequency of the system. For example an air column, closed at one end to operate as a quarter wave length system resonant at 30 hertz, has a length of more than nine feet, and still more than four feet long when folded. A typical ported reflex enclosure for a twelve

inch woofer, having a Q of 0.53, has an optimum volume of 6.75 cubic feet.

It is important to design a speaker system to have its resonant frequency not higher than the lowest frequency to be reproduced by the system. Resonant frequency depends on mass and stiffness, requiring increased mass and decreased stiffness to obtain lower resonant frequency. However, speakers for most applications require mounting in an enclosure to avoid interference between sound produced at front and back sides of the vibratory driver, e.g. the speaker cone, at low frequencies. The enclosure adds stiffness but little mass to the system. The smaller the enclosure, the higher its stiffness, and therefore, the higher the resonant frequency of the system. System mass is provided primarily by moving parts of the speaker itself so that more massive speakers are preferred for low frequency sound reproduction. Further, larger speakers requiring larger enclosures are desired for matching the acoustic impedance of air.

Ported reflex enclosures enhance efficiency but require larger enclosures for low frequency sound reproduction. Further, efficiency becomes less important as higher amplifier power becomes more widely and economically available. Excessive size of such systems is a significant drawback. Attempts to employ small diameter speakers and small enclosures for use at very low frequencies have not been successful. Small systems are less efficient because the small diameter speaker has a relatively poor impedance match with the acoustic impedance of ambient air. Consequently it is not common to employ loudspeaker transducers smaller than about eight inches in diameter to generate very low frequencies because of inefficient coupling to ambient air, and the higher stiffness introduced by smaller enclosures that frequently are used with the smaller speaker. Therefore, larger speakers have been employed, which inherently require

larger enclosures. Efficient, very low frequency speaker systems of suitable small size have not heretofore been available.

Accordingly, it is an object of the present invention to provide reproduction of low frequency sound with increased efficiency and smaller components.

SUMMARY OF THE INVENTION

In carrying out principles of the present invention in accordance with a preferred embodiment thereof a loudspeaker system having a low resonant frequency employs a speaker having a vibratory driver (such as a speaker cone) and a mass coupled with the driver for vibration with the driver. Means synchronized with the driver and cooperating therewith are provided for vibrating the mass in synchronism with the driver. In a particular embodiment the coupled vibratory mass comprises a mass of air confined between the vibratory driver and a second vibratory driver, with the two drivers being driven with like mechanical phase so as to vibrate the interposed body of air as a unit between the two drivers. The arrangement adds a large mass to the speaker system without significantly affecting stiffness of the system. One of the vibratory drivers is coupled to the vibratory air mass, and the other is coupled to both the vibratory air mass and ambient air.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 illustrates a basic concept for lowering resonant frequency of a speaker system in accordance with principles of the present invention;

FIG. 2 illustrates a modified form of the arrangement of FIG. 1; and

FIGS. 3 and 4 illustrate still further modifications.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, a rigid rectangular enclosure 10 of substantially conventional speaker enclosure construction and configuration is provided with a rigid continuous partition 12, which extends entirely across the enclosure and divides the enclosure into two substantially equal and identical closed halves 14,16, each defining a closed air chamber 18,20, respectively. Closed chambers 18,20 are of approximately equal volume and configuration. A first speaker 24 is mounted on partition 12. The latter is apertured to provide an aperture in the partition that is coextensive with the aperture of the cone 22 of the speaker. The cone, as is conventional in a common loudspeaker, is mounted to the speaker frame (not shown) and to the partition with a compliant mounting and is electromagnetically driven. The driven vibratory cone 22 may be termed a "vibratory driver" which causes vibration of the air in contact with the cone. Thus one side 21, which may be termed the "front side" of the cone 22 of speaker 24, is in contact with air within chamber 20, whereas the other side 23, which may be termed the "back side", of the cone is in contact with air confined within chamber 18.

Section 16 of the enclosure has a front or output wall 26 that is suitably apertured to mount a second conventional speaker 30, which may be identical to the speaker 24, and which also has a vibratory driver in the form of a cone 32 compliantly mounted to the speaker frame in a conventional manner.

The two speakers are driven in like mechanical phase so that they will impart like phase, like direction forces to the air mass of chamber 20 that is confined between the two. From one standpoint the two speakers may be considered to operate in "push pull". While one speaker cone moves in a direction that tends to push the confined air mass in such direction the other cone simultaneously

moves in the same direction and tends to "pull" the confined air mass in the same direction. In the configuration of FIG. 1 the two speakers are synchronized with each other and are in phase with each other both mechanically and electrically. The two speakers are electrically connected in parallel to be driven by the same electrical signal from one amplifier (not shown). The in phase operation is such that when cone 22 of speaker 24 moves toward the right, as viewed in FIG. 1, cone 32 of speaker 30 likewise moves toward the right, and visa versa. Accordingly, the operation of the two speakers upon the air mass of chamber 20 confined and interposed between the two speakers, causes vibration of the air as a unitary mass, with all parts of the air mass moving and vibrating in unison. The unitary mass of the vibratory air mass is synchronized with vibration of the speaker cones. The air mass in chamber 20 is not subject to alternate compression and expansion. The air mass in chamber 18, on the other hand is driven solely by the speaker 24 and is confined within the rigid enclosing walls of chamber 18. This body of air operates as a spring, being compressed when speaker cone 22 moves toward the left as viewed in FIG. 1, and expanding as the speaker cone moves toward the right. The air in chamber 18 adds primarily stiffness to the system, whereas air in chamber 20 adds primarily mass. Preferably the ratio of mass (inertance) of the air in chamber 20 to the stiffness of air in chamber 18 is between about 1 and 2.

With the described construction of the dual speaker, dual chamber enclosure of FIG. 1, there is provided a system that is effectively equivalent to a spring and mass oscillatory system, wherein the spring is provided by the air mass confined within enclosed chamber 18, and the mass is provided by the air mass confined within chamber 20.

The portion of the system including speaker 24 and the confined air in chamber 18 operates much as does a

conventional speaker system. The air mass in chamber 18 operates primarily as a spring and provides most of the system stiffness. Mass is provided for chamber 18 primarily by the relatively low mass components of the moving parts of speaker 24. The portion of the speaker system including both speakers and the air mass confined in chamber 20, on the other hand, operates not as a spring but primarily as a mass that is coupled to speaker 24 and that effectively couples speaker 24 to the ambient air. This is a coupled and coupling mass which includes the mass of the air in chamber 20 and the mass of the moving parts of the two speakers. For a chamber 20 of about one cubic feet enclosure and conventional eight inch speakers, the mass of the confined air in chamber 20 is considerably greater than the mass of the moving speaker parts. The air mass in chamber 20 is driven without compression or expansion, but effectively as a unitary vibratory mass, by the two in phase speakers on opposite sides of the air mass. Consequently the air mass merely adds to the mass of the total vibratory system. However, as mentioned above, the mass of the air within chamber 20 is considerably greater than the mass of moving components, such as cone, compliant movable elements and moving coil of either of the speakers, and thus significantly reduces the resonant frequency of the system. From one point of view, the confined air mass of chamber 20, together with the mass of moving parts of speaker 30, provides an additional mass that is coupled to the speaker system comprising the speaker 24 and chamber 18. As is well known, by increasing the mass of a vibratory system its resonant frequency is lowered.

In an exemplary system wherein the speakers are eight inches in diameter, and each of the chambers 18 and 20 has a volume of approximately one cubic foot, the added mass confined within chamber 20 is more than one ounce, which is considerably more than the approximately one-half ounce of mass of moving components of a typical eight inch speaker.

Thus in the described embodiment the addition of the mass of air in chamber 20 will decrease the natural resonant frequency of the system. Further, the addition of chamber 20 and speaker 30 drops the Q of the system and thus broadens the resonance peak.

Illustrated in FIG. 2 is a modification of the system of FIG. 1 comprising a rigid enclosure 110 divided in substantially equal halves of like configuration by a rigid continuous partition 112, upon which is mounted a first speaker 124. Speaker 124 operates upon the air confined within chamber 118 of the enclosure, which operates acts as a spring, providing primarily a stiffness in this resonant system. A second speaker 130 is mounted on an exterior wall 126 and contained within the second chamber 120 of the enclosure. Again, the two speakers are driven in like mechanical phase with each other with respect to the air confined within chamber 120, but in this arrangement are driven electrically 180° out of phase with each other. In FIG. 2, since the back of the cones of both speakers contact air confined within chamber 20, the two speakers must be driven out of phase, electrically, so that the two cones will apply like mechanical forces of like direction to the air within chamber 120. In other words, the two speakers are driven so that the motion of their cones are synchronized with each other and with the unitary motion of the air interposed between the two speaker cones within the chamber 120. The cones move in mutually aiding directions. Thus when cone 122 of speaker 124 is moving outwardly of air confined within chamber 120, that is, in the direction of arrow 123, cone 132 of speaker 130 is moving inwardly of the air in chamber 120, that is, in the direction of arrow 125. Thus the two speakers still apply like mechanical phase forces to the interposed air within chamber 120 to cause the latter to vibrate as a unit betw en the two speakers. In this embodiment, as in the arrangement of

FIG. 1, air in chamber 120 does not compress and then expand within the chamber, but moves as a unit.

The configuration of FIG. 1 may be more suitable to a tower speaker, where the long dimension of the enclosure is vertical, whereas the configuration of FIG. 2 is more suitable to a speaker system that is to be positioned with its long dimension horizontal.

If deemed necessary or desirable, any one of the configurations described herein may be vented, as shown for example by dotted line vent 140, shown in dotted lines in FIG. 2. Vent 140 represents a conventional vent tube extending into the interior of chamber 118 and open to ambient air at a vent port 142. This portion of the system (but without the added mass of chamber 120 and without the second speaker 130) is similar in configuration and restriction to a conventional ported reflex speaker enclosure. It has been found that the vented system of FIG. 2 is more efficient than the non-vented system. However, it is believed that the non-vented or enclosed system provides a more pleasing sound. Further, the enclosed, non-vented system has a considerably lower total harmonic distortion. With eight inch speakers the non-vented system has been found to have less than 2% total harmonic distortion at 40 hertz, whereas the vented system has a 6% total harmonic distortion, although it has somewhat higher efficiency in the vicinity of its resonant frequency.

In addition to increasing the mass and thereby significantly lowering resonant frequency of a system, the air mass within chamber 20 stabilizes both speakers in that it tends to minimize distortion of and provides support for speaker cones by reason of the unitary vibration on the entire air mass within the chamber.

Although speaker systems have been described in connection with a relatively small (eight inch apertur) speaker, principles of the invention also apply to larger

speakers. Even though such speakers can be made with greater mass, the addition of the vibratory air mass enables a still lower resonant frequency. To minimize system space requirements, it is desirable to mount the larger speaker in a smaller enclosure. However, the smaller the enclosure the greater the stiffness of the confined air, and therefor the higher the resonant frequency of the enclosed speaker. The described systems enables even the larger speaker to be mounted in a smaller enclosure. Increased stiffness of the smaller enclosure is compensated, at least in part, by coupling the added mass of air confined within the second chamber 120 in FIGS. 1 and 2 and causing such confined air to act as a mass rather than a spring.

Illustrated in FIG. 3 is a further modification in which a rigid enclosure 210 has a fixed, continuous partition 212 to which is mounted a first speaker 224 cooperating with an air mass within chamber 218, which acts primarily as a spring in this resonant system. A second speaker 230 is mounted on an exterior wall 226 of the second chamber 220. The two speakers are driven in phase (both electrically and mechanically, in this arrangement) so as to apply like direction ("push-pull") forces to the confined and interposed body of air in chamber 220 to cause this body of air to effectively move as a vibratory unit, without compression and expansion, between the speakers.

Again the confined body of air within chamber 220, driven as a unitary vibratory mass and coupled with speaker 224, adds a significant amount of mass to the oscillatory speaker system, thereby significantly lowering its resonant frequency.

Illustrated in FIG. 4 is a system that is identical to that shown in FIG. 3, except that the chamber 226 (which provides most of the stiffness of the system) is provided with a vent tube 240 connected to a port 242 in the wall of an enclosure that mounts th two speakers 224 and 230.

Again, the body of air confined within chamber 220 acts as a vibratory mass to significantly lower the natural frequency of the system, whereas the speaker 224 and air within chamber 226 acts as a conventional speaker with a vented (ported reflex) enclosure. The arrangements of FIGS. 3 and 4 operate just the same as the arrangements of FIGS. 1 and 2, and the comments made with respect to those earlier described embodiments apply equally to the embodiments of FIGS. 3 and 4.

In all embodiments disclosed herein the speakers are displaced from one another along the axis of at least one of the speakers, thereby positioning the speakers for "push-pull" operation upon the interposed body of air. Either speaker can have either the front side or back side of its speaker cone facing air in either chamber, as long as the speakers exert "push-pull" forces on the vibratory air mass to cause it to vibrate as a unit.

There have been described loudspeaker systems which provide significantly decreased resonant frequency with use of smaller enclosures by provision of a vibratory mass that is caused to vibrate in synchronism with the electrical signal that produces the speaker vibration. The arrangement is such that one confined air mass operates as a spring that primarily provides stiffness of the resonant system, whereas a second confined air mass is driven by forces applied by speakers on two different sides thereof to move effectively as a vibratory unit rather than to compress and to expand. Thus mass is added to the system in a simple, efficient manner that enables use of a smaller enclosure at very low frequencies.

CLAIMS

What is Claimed is:

1. A loudspeaker system having a low resonant frequency comprising:

a speaker having a vibratory driver,

a vibratory mass coupled with said driver for vibration therewith, and

means synchronized with said vibratory driver and cooperating therewith for vibrating said mass in synchronism with said driver.

2. The system of Claim 1 wherein the mass of said vibratory mass is greater than the mass of moving parts of said speaker.

3. The system of Claim 1 wherein said vibratory mass is interposed between said speaker and ambient space.

4. The system of Claim 1 wherein said vibratory mass comprises a body of air that is not subjected to compression and expansion by said vibratory driver.

5. The system of Claim 1 wherein said vibratory mass comprises a body of air that is vibrated as a unit without significant compression and expansion.

6. The system of claim 1 including means for coupling said mass to ambient space.

7. The system of Claim 6 wherein said means for coupling said mass comprises a second speaker having a second vibratory driver.

8. The system of Claim 1 wherein said means synchronized with said vibratory driver comprises a second vibratory driver, said mass comprising a body of air confined between said vibratory drivers.

9. The system of Claim 8 including means for driving both said drivers in a phase relation that causes the drivers to exert mutually in phase forces upon said body of air to cause vibration of said body of air as a unit between said drivers.

10. The system of Claim 9 including an enclosure having a partition dividing the enclosure into first and second chambers, said speaker being mounted to said partition, said second chamber having an exterior wall, a second speaker mounted in said exterior wall, said second vibratory driver forming part of said second speaker, said mass comprising a body of air confined within said second chamber.

11. The system of Claim 10 including means for venting said first chamber.

12. The system of Claim 10 wherein said first chamber includes a vent tube coupling the interior of said first chamber with ambient air.

13. A low resonance speaker system comprising:

a speaker having a vibratory driver,

massive means for coupling said driver to ambient space, said massive means comprising a confined body of air interposed between said driver and ambient space, and

means for vibrating said body of air as a unit in synchronism with said vibratory driver.

14. The system of Claim 13 wherein said means for vibrating comprises means that applies force to said body of air without tending to compress said body of air.

15. The system of Claim 13 wherein said means for vibrating comprises a second vibratory driver between said body of air and ambient space, and means for vibrating both said drivers in phase with each other and with said confined body of air.

16. The system of Claim 15 wherein said body of air is confined between said vibratory drivers.

17. A loud speaker system comprising:

an enclosure,

a partition dividing the enclosure into first and second chambers, said second chamber having an exterior wall,

a first speaker mounted to said partition,

a second speaker mounted to said exterior wall, and

means for driving said first and second speakers so as to cause air confined within said second chamber to move as a unit between said first and second speakers.

18. The system of Claim 17 including a vent formed in said first chamber.

19. The system of Claim 17 wherein said first speaker is mounted within said first chamber and said second speaker is mounted within said second chamber.

20. The system of Claim 17 wherein both said first and second speakers ar mounted within said second chamber.

21. The system of Claim 17 wherein said speakers each have a driving cone with front and back surfaces and a speaker axis, said first speaker being mounted with the front surface of its cone facing air in said second chamber, and said second speaker being mounted with the back surface of its cone facing air in said second chamber and being spaced from said first speaker in the direction of at least one of said speaker axes.

22. The system of Claim 1 wherein each said speaker includes a cone having front and back surfaces, wherein said first speaker is mounted to said partition with the back surface of its cone in contact with air in said second chamber, and wherein said second speaker is mounted in said second chamber with the back surface of its cone in contact with air within said second chamber, said first speaker having the front surface of its cone in contact with air within said first chamber.

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Relevant T chnical fi lds

(i) UK Cl (Edition K) H4J(JAB,JBA)

(ii) Int Cl (Edition 5) H04R 1/20, 1/22, 1/28

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

E J EASTERFIELD

Date of Search

25 AUGUST 1992

Documents considered relevant following a search in respect of claims 1-22

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X	US 4064966 A (BURTON) especially Figure 3	1,2,4-14, 17,18,20, 22
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Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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